# Welfare, Market Power, and Price Effects of Product Diversity: Canned Juices

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# Questions

What effect does the introduction or elimination of a differentiated product have on

- consumer surplus, producer surplus, welfare,
- Lerner measures of price markups,
- prices?

# Why Care

- Food industries have rapid entry and exit of items, brands, and firms.
- Theoretical debate: Is there too little or too much differentiation?

# Two types of product innovations

- *New contents* (new flavor, add carbonation,...)
- *New size or package*

# New Contents

- Snapple's 2000 U.S. fruit drinks:
  - Diet Orange Carrot Fruit Drink
  - Raspberry Peach Fruit Drink
- Proctor & Gamble's new German Punica fruit juice drinks:
  - Canned carbonated drink: Punica Fruitshot
  - Aimed at teenagers

# New size of package

- Welch's (National Grape Cooperative Assoc. Inc.) introduced new sizes
- Leads to relocation
  - Before: in one section of supermarkets
  - Now: in many supermarket aisles, vending machines, convenience stores, and membership wholesale clubs.

# *Innovation is faster now*

- 1999: 1/3 of Welch's sales from products introduced within the last 5 years
- Early 1990s: New products accounted for only 1/10  of overall sales

# Theoretical literature on optimal differentiation

- Spence 1976, Dixit-Stiglitz 1977, Salop 1979
- Deneckere and Rothschild (1986) model nests
  - Salop spatial model
  - Perloff-Salop representative consumer model

# Deneckere and Rothschild

- Adding a brand benefits fewer consumers in spatial than in representative consumer model
- Consequently
  - too many brands in a spatial model (competition is localized)
  - too many or too few in a representative consumer model

# Small empirical literature on welfare

- Hausman (1996) and Nevo (2000): cereal
- They concentrate on the implications for measuring the consumer price index

# Large empirical literature: Effects of entry on prices/market power

- Hausman (1996): price effects on similar products from entry of a new cereal
- Kadiyali, Vilcassim, and Chintagunta (1999): When 1 of 2 national yogurt manufacturers introduces a new variant, it gains price-setting power; firms' combined sales increase

# Outline

- Discuss theoretical implications of a linear random utility demand system for oligopoly equilibrium
- Show how to estimate theoretical model using a random-parameter, discrete choice model
- Present our estimates of demand
- Simulate market power, price, and welfare effects

# Linear Random Utility Model

- Perloff-Salop (1985) model (see also Anderson-de Palma-Thisse 1992)
- Each of the $i = 1, \ldots, n$ firms produces a differentiated product with quantity $Q_i$
- Each of $j = 1, \ldots, N$ consumers buys 1 unit: $S_i \; Q_i = N$

# Consumer *j*'s conditional indirect utility is

$$\tilde{V}_{ij} = a - p_i + qz_{\text{ij}},$$

where

- $a$ = attribute or quality of a good
- $p_{\text{i}}$ = real price of firm *i*'s product
- $z_{ij}$ = a random variable with mean zero, distributed IID $F$(.) with density $f$ (.)
- $q$ = preference intensity: the larger $q$, the less important price is in determining the variant a consumer buys

# Nash-Bertrand Equilibrium Price

- Let $m$ = constant marginal cost
- Symmetric short-run equilibrium price is

$$p = c + q\,/[n(n-1)\hat{\Gamma}(n)],$$

- where

$$\hat{\Gamma}(n) = \int_{-\infty}^{\infty} f^{2}(z)[F(z)]^{n-2}\,dz\,.$$

- Thus,
  - markup is proportional to $q$
  - $p$ is proportional $c$.

# Effect of Entry on Price

- Adding One More Firm
  - decreases the short-run equilibrium *p* iff
    $$(n+1)\hat{\Gamma}(n+1)-(n-1)\hat{\Gamma}(n)>0$$
  - *p* decreases with 1 more firm for logit
- Infinite number of firms ($n\rightarrow\infty$): $p\rightarrow m$ *if*
  - *f*(.) is bounded from above, or
  - $\lim_{z\rightarrow\infty} f'(z)/f(z)=-\infty$

# Effect of Entry on Price

- Probit: $p \rightarrow m$
- Logit: $p \rightarrow m + m = m + s\sqrt{6}/p$

# Generalized Random Utility Model

- Each firm sells one or more products indexed by *i*
- In each period, the indirect utility for consumer *j* is

$$\hat{V}_{ij} = a_i - p_i + e_{ij} + z_{ij},$$

  - $\varepsilon_{ij}$ ~ multivariate normal
  - $\zeta_{ij}$ ~ IID extreme value
- 2 error terms with different distributions $\Rightarrow$ equilibrium properties $\neq$ those of pure logit or probit

# Relation to Logit

- Integrating out $\varepsilon_{ij}$, we get a logit-like specification
- AdPT show that a representative consumer's utility function (suppressing *j*) consistent with this model is

$$U = \begin{cases} \sum_{i=1}^{n} a_i Q_i - \mu \sum_{i=1}^{n} Q_i \ln \frac{Q_i}{N} + Q_0 & if \sum_{i=1}^{n} Q_i = N, \\ -\infty & \text{otherwise} \end{cases}$$

- Second term on RHS is $\mu \times N \times$entropy

# Two Interpretations of μ

1. Scale parameter in logit
2. AdPT show μ plays same role as θ in PS model
   - It captures variety-seeking behavior of the representative consumer
   - Larger μ $\Rightarrow$ greater preference for diversity.
     - $\mu \to 0 \Rightarrow$ diversity not valued; consumer buys only variant with largest net surplus = $a_i - p_i$
     - $\mu \to \infty \Rightarrow$ consumption is divided equally among all available variants.

# Random-Parameter Discrete-Choice Model

- Use random-parameter discrete-choice model to estimate theoretical model
  - Berry, Levinsohn, and Pakes (1995)
  - Nevo (2000)
- We
  - don't observe individuals' choices
  - do observe aggregate choice
  - model demand as depending on observed and unobserved product characteristics and price
  - capture these unobserved effects using random parameters

# Random-Parameter Logit

- RPL generalizes logit
- Allows coefficients of characteristics, $ß_j$, to vary randomly over characteristics rather than be fixed

# Conditional Indirect Utility

Consumer *j*'s conditional indirect utility for item *i* in period *t* is

$$\hat{V}_{ij} = X_{ij}(b + h_{ij}) + z_{ijt} = X_{ij} b + e_{ijt} + z_{ijt}$$

- $X_{it}$ = vector of observed product characteristics
- $\beta$ = vector of population means
- $\eta_j$ = individual deviationj (consumer's taste relative to the average tastes) ~ IID normal
- $\zeta_{ijt}$ = an unobserved random term~ IID type 1 extreme value

# Estimation

- We can estimate ß, but we do not observe $\eta_j$ for each consumer
- Thus, the unobserved portion of utility,

$$X_{it}\eta_j + \zeta_{ijt} \equiv \varepsilon_{ijt} + \zeta_{ijt},$$

  is correlated over products and time because of the common term $\eta_j$

# RPL vs Logit

- RPL avoids unattractive restrictions of the usual logit or nested logit models:

| | *Logit, Nested Logit* | *RPL* |
|---|---|---|
| Coefficients | same for all products and time | vary over products and time |
| IIA | yes (within nests) | no |

- McFadden and Train show that RPL can appx. any substitution patter

# Demand Equations

- Suppressing time, *t*, index and integrating out the $?_{ij}$ ~ IID extreme value, we get share for item *i* purchased by individual *j*:
- $$\tilde{S}_{ij} = \frac{e^{(X_i b - p_i + e_{ij})/m}}{\sum_{l=1}^{n} e^{(X_l b - p_l + e_{lj})/m}}$$

# Simplifying Demand Equation

- Integrate out the population distribution of the taste parameter $\varepsilon_{ij}$ ~ IID normal and obtain item share:

$$S_i = \int \tilde{S}_{ij} f(e)\mathrm{d}e$$

- Total number of units purchased is *N*, so demand equations are

$$Q_i = NS_i.$$

# Expenditure Function

Expenditure function is

$$Z = \bar{U} - Nm \ln\left[ \int \sum_{i=1}^{n} e^{(a_i - p_i + e_{ij})/m} f(e) \mathrm{d}e \right]$$

for any utility level

# Integrating

- High-dimensional integrals are difficult to calculate analytically
- Thus, we approximate product share using simulations

# Simulations

- $S_i$ is approximated by a sum over randomly chosen values of $\varepsilon_{ij}$
- $\varepsilon_{ij}$ is drawn 50x from its distribution
- Get unbiased estimator, whose variance decreases as number of draws increases
- Simulated estimator is smooth, strictly > 0 for any realization of finite draws, so log of simulated probability is always defined
- Under regularity conditions, estimator is consistent and asymptotically normal

# Own Elasticities

- Own price elasticity for item *i* is

$$E_{ii} = \frac{p_i}{\mu S_i} \int \tilde{S}_{ij} \left( \tilde{S}_{ij} - 1 \right) f\left(\mathrm{e}\right) d\mathrm{e}$$

- Standard logit:
  - $E_{ii} = p_i(S_i - 1)$
  - Own price elasticity is proportional to price

# Cross-Price Elasticity

- Cross-price elasticity (effect of a change in price of *k* on quantity of *i*) is

$$E_{ik} = \frac{p_k}{\mu S_i} \int \tilde{S}_{ij} \tilde{S}_{kj} f(\mathrm{e}) \mathrm{de} > 0$$

- Standard logit: $E_{ik} = p_k S_k$.

# Price Effects

- *Theorem*:  An increase in one good's price, holding all other goods' prices fixed, causes the shares of other goods to rise for *any* discrete-choice model
- Therefore,
  - In logit, elimination of a good $\Rightarrow$
    - other goods' shares rise $\Rightarrow$
    - other goods' own price elasticities rise $\Rightarrow$
    - prices of all other goods rise
  - In our model, price may rise or fall

# Data

- Information Resources Incorporated's InfoScan$^{TM}$ data
- National grocery store data
- Covers 29 “months” of 4 weeks each (13 months to a year)
  - First month ends December 8, 1996
  - Last month ends January 31, 1999

# Popular Canned Products

- *Flavor*:
  - vegetable
  - fruit punch
  - tomato
  - pineapple
  - apple
  - grape
  - citrus
- *Type*:
  - juice
  - juice drink
  - nectar
  - drink
  - juice cocktail
- *Count*:
  - 1
  - 6
  - 12
  - 24
  - 4

# 10 Best Selling Items

| | Oz. | % Best Seller |
|---|---|---|
| V8 Canned Vegetable Juice (Campbell Soup) | 46 | 100 |
| Dole Pineapple Canned Fruit Juice (Dole) | 46 | 64 |
| Juicy Juice Fruit Punch (Nestle) | 46 | 61 |
| Seneca Apple Juice (Seneca) | 46 | 52 |
| Juicy Juice Grape Juice (Nestle) | 46 | 49 |
| Campbell's Tomato Juice (Campbell) | 46 | 49 |
| Juicy Juice Cherry Juice (Nestle) | 46 | 48 |
| Juicy Juice Berry Blend Juice (Nestle) | 46 | 48 |
| V8 Canned Vegetable Juice, 6 count | 69 | 46 |
| Hawaiian Punch, 12 count | 144 | 44 |

# Endogeneity

- Unobserved quality variation may introduce spurious correlation between average price and average sales across brands
- Low-quality brand would tend to have fewer sales than other brands for some fixed price
- However, lower quality item is likely to have a relatively low price (firm chooses price optimally)
- To account for this source of endogeneity, we use a fixed-effects model with a dummy for each brand to capture unobserved quality variation at brand level
- Hausman-Wu test strongly rejects the alternative hypothesis of random effects

| | ß/μ | | ß/μ |
|---|---|---|---|
| Price ($) | -3.638* | Nectar Drink x Time | 0.005 |
| Feature & Display (%) | 0.036 | Nectar x Time | 0.084 |
| Display Only (%) | 0.012 | Sparkling Juice Drink x Time | -0.294* |
| Feature Only (%) | -0.003 | Flavor (28) | 0.515 |
| Size (oz) | -0.011 | Firm (70) | 0.448 |
| Count (# of cans) | 0.098* | Type (8) | 2.172* |
| Size/Count | 0.014 | Brand (104) | 0.368* |
| Drink x Time | 0.055 | Item (421) | 0.337 |
| Juice x Time | 0.172* | Size | 0.001 |
| Juice Cocktail x Time | -0.068 | Count | 0.016 |
| Juice Drink x Time | 0.046 | Size/ Count | 0.057 |

# Diversity (Slightly) Matters

- AdPT diversity coefficient is
  $\mu$ = -1/price coefficient = 0.275
- Asymptotic standard error = 0.0058, so we reject the hypothesis that $\mu = 0$
- Nonetheless, $\mu$ is closer to 0 than to $\infty$
- $\mu = 0 \Rightarrow$ consumer buys only the variant with the largest net surplus; low value on diversity

# Market Power

- Single-product firm's Lerner index is

$$L = (p - m)/p = -1/e$$

- $e$ = own price elasticity

# Profit

- Multiproduct firm's profit/period in a Bertrand-Nash equilibrium:

$$\mathrm{p} = \sum_{k=1}^{m} \left( p_k - m_k \right) Q_k - hF - \tilde{F},$$

- $k$ indexes only firm's $h$ items
- $m_k$ = firm's marginal cost for item $k$
- $F$ = item fixed cost
- $\tilde{F}$ = firm's overall fixed cost

# Multiproduct Profit Maximization

- The first-order condition is

$$\hat{L} = -(E')^{-1}S$$

- $S$ = vector of shares of the items
- $\hat{L}$ = vector whose $k^{\text{th}}$ element is $L_k$ x $S_k$
- $L_k$ = Lerner index for item $k$
- $S_k$ = item $k$'s share (of the firms total sales).
- Weighted elasticity = *multiproduct elasticity* (less elastic than own-price elasticity).

# Price Effects

- Effect of entry or exit on price:
- Holding *MC* constant, we calculate the average price change from period 0 to period 1 as

$$\mathrm{S}_i\ [p_i(1) - p_i(0)]q_i(0)\ /\ [\mathrm{S}_i\ p_i(0)q_i(0)]$$

# Price Effects from Eliminating Pineapple Juice Products

*Price Effect (%) on*

| *Eliminated Pineapple Products* | *Dole's 6-Pack of 6 oz Cans* | *Other Pineapple Products* | *Non-Pineapple Products* |
|---|---|---|---|
| Dole's 46 oz can | -4.1 | 0.3 | 0.8 |
| All Dole products | - | 0.8 | 0.9 |
| All pineapple products | - | - | 1.0 |

# Consumer Surplus

Because income is fixed, consumer surplus (CS) using expenditure function (CV = EV)

# Experiment

- Eliminate Dole’s 46 oz pineapple juice can: price $\rightarrow$ to choke price (or $\infty$)
- Holding total quantity fixed,
  - 5.8% of quantity to Dole’s 6 pack or 6 oz cans
  - 3.4% to other pineapple juices
  - 90.7% to other products
- Thus, consumers do not view small cans of Dole pineapple juice or other pineapple juices as close substitutes for Dole’s large can

# Eliminate Dole 46 oz ($million/month)

| *Eliminate Dole 46 oz* | *Quantity Only* | *Quantity & Price* |
|---|---|---|
| Consumer Surplus | -345 | -495 |
| Producer Surplus | -355 | -301 |
| Welfare | -700 | -796 |

# Eliminate All Dole Pineapple

| *Eliminate All Dole* | *Quantity Only* | *Quantity & Price* |
|---|---|---|
| Consumer Surplus | -916 | -1,183 |
| Producer Surplus | 210 | 417 |
| Welfare | -706 | -766 |

# Eliminate All Pineapple

| *Eliminate All Pineapple* | *Quantity Only* | *Quantity & Price* |
|---|---|---|
| Consumer Surplus | -1,391 | -1,677 |
| Producer Surplus | 497 | 720 |
| Welfare | -894 | -957 |

# Actual Entry & Exit

- Entry: Jugos was a major "near" entrant during our period, going from trivial to major sales of Del Valle nectar and nectar drinks
- Exit: over our period, Conagra's vegetable juice division sales (Hunt's tomato juice) essentially disappeared

# "Entry" by Jugos
# ($million/month)

| *"Entry" by Jugos* | *Quantity Only* | *Quantity & Price* |
|---|---|---|
| Consumer Surplus | 84.3 | 130.3 |
| Producer Surplus | 85.6 | 51.6 |
| Welfare | 169.9 | 181.8 |

# "Exit" by Conagra ($million/month)

| *"Exit" by Conagra* | *Quantity Only* | *Quantity & Price* |
|---|---|---|
| Consumer Surplus | -20.8 | -52.4 |
| Producer Surplus | -248.9 | -227.9 |
| Welfare | -269.7 | -280.2 |

# Welfare Effects of Eliminating a Large Firm (allowing prices to adjust) $million/month

| | ? *PS* | ? *CS* | ? *W* | \|? *W*\|/R |
|---|---|---|---|---|
| Nestle Canned Fruit Juice | 2.05 | -14.69 | -12.65 | 1.20 |
| Campbell Soup | 0.76 | -2.29 | -1.54 | 0.39 |
| Procter & Gamble | 0.11 | -4.32 | -4.21 | 1.41 |
| Dole | 0.69 | -1.47 | -0.78 | 0.34 |
| Nestle Canned Juice Drinks | -0.12 | -0.69 | -0.81 | 0.42 |
| Citrus World | 0.37 | -1.13 | -0.77 | 0.46 |
| Texas Citrus Exchange | 1.05 | -1.51 | -0.47 | 0.38 |
| Empacadora de Frutas | -0.11 | -0.52 | -0.63 | 0.65 |

# Summary

- Estimated a system of demands for canned juices using
  - random-parameter, discrete-choice model
  - with extreme value and normal errors
  - for a large number of firms and items
- Purpose: Determine welfare effects of
  - product diversity
  - entry and exit
  - mergers…

# Conclusions

- Consumers place a relatively low value on variety
- Branded canned juice companies exercise substantial market power
- An exit leads to only moderately price changes in other products
- Allowing price to adjust usually leads to larger estimated welfare effects
- Entry or exit of a firm in this market has large welfare effects: larger than but of the same order of magnitude as revenue

# Extensions: Mergers

- We can use the same type of analysis to examine the effects of mergers on
  - prices
  - welfare
- We can determine if the merger guidelines are reasonable for a given industry by simulating